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Investigating the Thermal Comfort of Aboriginal Housing in Walgett, NSW & Identifying Opportunities for Improvement

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Abstract
While there are a handful of studies that investigate the thermal comfort and retrofit potential of Australian residential buildings, there are very few that do so with a specific focus on social housing, and none that do so with a focus on Aboriginal Housing. This study aims to investigate the thermal comfort of Aboriginal Housing services in Walgett, NSW and identify ways in which the thermal performance of such housing can be improved, by using passive design strategies to retrofit the building envelope. When Australian House Energy Rating software *FirstRate5* was used to build thermal models of four typical houses belonging to the Aboriginal Housing Office's existing housing stock in Walgett, it was found that the average House Energy Rating of the houses, when modelled for all primary orientations, was 1.3 stars. When the building envelope retrofit potential of the houses was investigated using the *FirstRate5* software, it was observed that the average House Energy Rating of the houses could be improved 5.2 stars – when the houses are retrofitted with: reflective foil in the roof space, R4.0 insulation to the ceiling, R1.5 insulation to external walls, awnings to external glazing systems and R1.0 insulation to the floor.

1. Introduction

Thermal comfort is recognised as one of the most important aims of building design (Raish, n.d.). While thermal comfort is a subjective measure, defined as a building occupant's "condition of mind that expresses satisfaction with the thermal environment" (ANSI/ASHRAE Standard 55, 2013), the benefits of thermal comfort are certainly far reaching. By achieving good thermal comfort via the optimisation of building envelope and ventilation, building design can promote health, while also decreasing electricity bills and carbon emissions (WHO, 2018). Additionally, it has been reported that improving thermal comfort contributes to improved educational outcomes, as well as reducing days off school and work (WHO, 2018).

In Australia, low income earners with housing needs are eligible to apply for secure and affordable rental housing (FACS, 2019). One of the biggest providers of Aboriginal-specific housing services in NSW is the Aboriginal Housing Office (AHO). Of the 5,793 properties belonging to the AHO's NSW housing portfolio, 81% are categorised as State Owned and Managed Indigenous Housing (SOMIH) and are managed by the Department of Family and Community Services (FACS) (AHURI, 2017). Together with Aboriginal Community Housing Providers (ACHPs), the AHO are responsible for a number of tasks including the procurement, construction, operation and maintenance of their housing stock (AHURI, 2017).

Further, while almost three million Australians are living below the poverty line in Australia, it is highly likely that the number who are living in energy poverty is far greater (ACOSS, 2017). Heartbreakingly, a recent KPMG publication reports that those Australians most vulnerable to energy poverty are low-income large-family households in Aboriginal communities (KPMG, 2017). With the price of Australian electricity having risen by 76% over the past 10 years (ACOSS, 2017), low-income households are going to great lengths to pay increasing electricity bills, including:

- Sacrificing healthcare, healthy food and education (Moore et al., 2017).
- Rationing money for new clothes (KPMG, 2017).
- Avoiding transport (NCOSS, 2017).
- Going without heating and cooling (KPMG, 2017).

Under the Aboriginal Housing Act 1998 (NSW), the AHO has a legal obligation to ensure that "Aboriginal and Torres Strait Islander people have access to quality, and affordable housing" (AHO, 2014). The AHO therefore aims to provide housing solutions that are both thermally comfortable and efficient to operate. Given the extensive benefits that can be derived from thermal comfort, in September 2016, the AHO announced that under the *AHO Air Conditioning Policy* it would "install air-conditioning systems in AHO houses in areas with high summer temperatures" (AHO, 2017).

Under this scheme, "reverse cycle split system air-conditioning" (AHO, 2017) was installed in the living areas of "all houses located at or above Isotherm 33°C in NSW" (AHO, 2017) as a means to improve thermal comfort, and respond to householder feedback that "homes get very hot in summer" (AHO, 2017). While the intent of the *AHO Air Conditioning Policy* is to be applauded, to inform future effects in this area, it is important to understand the heating and cooling requirements of these homes, and how these requirements can be minimised by retrofitting building envelopes – especially given what is known about energy poverty in Australia's Aboriginal communities.

Presently, the region of New South Wales that Walgett belongs to experiences approximately 80 *hot days* (days where the maximum temperature exceeds 35°C) a year (Office of Environment and Heritage, 2014). Given that Walgett is expected to experience an additional 10-20 *hot days* per year in the near future (2020-2039), and an additional 40 *hot days* per year by 2070 (Office of Environment and Heritage, 2014), it is crucial that options for improving thermal comfort are explored. It is important that the homes of Australia's most vulnerable citizens will not just be thermally comfortable in these conditions, but also that this thermal comfort can be achieved affordably, and with minimal reliance on mechanical heating and cooling systems. This is important for two reasons:

1. To ensure that the thermal comfort and health of Aboriginal householders in Walgett will not be overly compromised in the event of a power outage;
2. To ensure that the Aboriginal householders in Walgett do not become at higher risk of energy poverty/that the ramifications of energy poverty in Walgett already felt by Aboriginal householders are not intensified.

One way in which the heating and cooling requirements of an existing building can be reduced, and hence its dependence on air-conditioning for thermal comfort, is by retrofitting the building envelope. In fact, it is widely recognised that in the residential sector, retrofits for existing housing stock is the low hanging fruit for energy savings and greenhouse emissions reductions (McNicol, 2017). In a 2010 study conducted by Sustainability Victoria and the Moreland Energy Foundation Limited, Nationwide House Energy Rating Scheme (NatHERS) assessments were performed on 15 pre-1990 homes, using the NatHERS accredited software *FirstRate5* (SV/MEFL, 2010). By considering a residential dwelling's design, and the location it is to be built in, NatHERS assessments assign a home with a score out of ten for its predicted thermal performance. By making modifications to the building envelope of each of the houses, it was shown that the average House Energy Rating (HER) of the 15 homes could be improved from 1.3 stars to 4.3 stars (SV/MEFL, 2010).

Although the results of the 2010 study have little numerical significance for this study (given that the 2010 study was conducted for the heating dominated climate of Melbourne, and that this study is being conducted for the cooling dominated climate of Walgett), the experimental procedure employed to attain these results is of particular interest. Moreover, a building energy tool, such as *FirstRate5*, could be used to perform thermal modelling of residential dwellings typical of those belonging to Aboriginal Housing in Walgett, and investigate their building envelope retrofit potential: providing insight that is yet to be documented within thermal comfort literature.

Therefore, this paper aims to address the following research questions:

1. How thermally comfortable is existing Aboriginal housing in Walgett?
2. How can retrofitting the building envelope of Aboriginal housing in Walgett improve thermal comfort?
3. What are the operational energy costs associated with providing heating and cooling to Aboriginal housing under the *AHO's Air Conditioning Policy*?

2. Methodology

In order to better understand the thermal comfort of existing Aboriginal Housing in Walgett, and ways in which the thermal comfort of these dwellings can be improved by passive design, a methodology that is loosely based on that of the Sustainability Victoria/Moreland Energy Foundation Limited studies, has been utilised. The methodology can be summarised as follows:

1. Obtain architectural drawings for houses typical of those belonging to the existing Aboriginal Housing stock in Walgett.
2. Develop *FirstRate5* models of the houses, using the architectural drawings. The modelling results used to better understand the thermal comfort of these homes by analysing heating and cooling loads.
    a. Run the models in *FirstRate5*'s "rating mode" to determine the home's star rating under NatHERS.
    b. Run the models in *FirstRate5*'s "non-rating mode", with heating and cooling only applied to the living room, to better understand the heating and cooling requirements of the homes when only this living room is conditioned (as is the case with Aboriginal Housing under the AHO's Air Conditioning Policy).
3. Make modifications to the building envelope of the modelled houses to investigate how effectively building envelope retrofits could improve the thermal comfort of homes.
    a. Run the models in *FirstRate5*'s "rating mode" to determine the home's star rating under NatHERS, after each retrofit has been made.
    b. Run the models in *FirstRate5*'s "non-rating mode", with heating and cooling only applied to the living room, to better understand the heating and cooling requirements of the homes when only this living room is conditioned (as is the case with Aboriginal Housing under the AHO's Air Conditioning Policy), after each retrofit has been made.
4. Calculating operational energy savings that could be resultant of each building envelope retrofit for each home.

For this study, it was assumed that the houses were operating under a flat tariff equal to Simple Energy's retail electricity price for residents in Walgett, as at 2019 (24.39c/kWh; Simple Energy, 2019).

While this methodology allows for the different houses to be assessed in a standardised manner (using the default NatHERS profiles for occupancy rates and the operation of heating and cooling systems), it is worth noting that there are a few issues with using NatHERS accredited software such as *FirstRate5* to investigate the thermal comfort of the existing Aboriginal Housing stock in Walgett. Firstly, under NatHERS protocol, Walgett falls under the Moree Climate Zone, meaning that the weather file used to assess the thermal comfort of the dwellings is not specific to Walgett. Further, the Moree climate file used by *FirstRate5* uses 1992 as the reference year – meaning that this weather file does not take into account increases in temperature over the past 27 years or drought impacts.

Additionally, the modelling assumes the default NatHERS profiles for occupancy and the operation of heating and cooling systems – this could be problematic, as these profiles are not specific to social housing, and the way that social housing may be operated. Further qualitative research would be required to confirm whether these default profiles are reflective of the ways that Aboriginal Housing in Walgett is operated in reality.

3. Results

For this study, four different sets of architectural drawings for houses typical of those belonging to the existing Aboriginal Housing stock in Walgett were obtained. Table 1 summarises the constructions of these houses as they appear on the architectural drawings, and as they've been modelled in *FirstRate5*. Table 1 also reports the annual heating and cooling energy requirements for these homes, as calculated by *FirstRate5*, and their corresponding House Energy Ratings (HERs). Given that there is no information outlining the orientation of these houses, the houses have been modelled for orientations of 0°, 90°, 180°, 270°.

Table 1: The Base Case Constructions and Thermal Performance Results for Four Typical Houses Belonging to the Aboriginal Housing Stock in Walgett

	House 1	House 2	House 3	House 4
Number of Bedrooms	3	3	3	3
Number of Bathrooms	1	1	1	1
Floor Area of House (m^2)	74.7	77.6	67.2	64.1
Construction of External Waslls	Brick Veneer (Brickwork/130mm Air Gap/Plasterboard; No Insulation)			
Construction of Internal Walls	Plasterboard (Plasterboard/90mm Air Gap/Plasterboard)			
Construction of Ceiling	Plasterboard (No Insulation)			
Construction of Roof	Discontinuous (No Insulation; Medium Colour)			
Construction of Floors	Concrete Slab on Ground (No Insulation)			
Floor Coverings	Kitchen/Living – Timber, Bedrooms – Carpet, Wet Areas - Tiles			
Glazing	Aluminium Framed Single Glazed Clear (U = 6.7 W/m^2K, SHGC = 0.57)			
Glazing to Floor Area Ratio (%)	12.9	18.3	33.6	22.6

Observation of Table 1 reveals that all of the houses are comprised of the same constructions, and that the houses contain no insulation, and very limited thermal mass. This suggests that the building envelope of these houses is very poor, and that it is unlikely that these houses will be able to easily maintain thermally comfortable conditions. These suspicions are confirmed in Table 2, which presents the FirstRate5 results for the houses; reporting the area standardised, annual heating and cooling loads for the houses, along with their NatHERS HER.

From Table 2, it is clear that the thermal performance of all four houses is very poor, with the houses having an average HER of 1.3. Considering that in Australia, all new and renovated houses must have achieve a minimum HER of 6 (ABCB, 2019), it can be concluded that the existing Aboriginal housing in Walgett falls significantly below the national minimum energy efficiency requirements. While it is not unusual for Australia's existing housing stock to fall below today's minimum energy efficiency requirements (the average HER of the existing houses in the MEFL/SV study was 1.81 stars), it is hugely concerning that the thermal performance of Aboriginal housing is so poor. This is the case for two main reasons:

1. Aboriginal housing providers have a legal obligation to ensure that they provide quality and affordable housing. Therefore, it is to be expected that the housing provided to Aboriginal Australians is of reasonable quality.
2. It is known that Aboriginal householders are highly vulnerable to energy poverty. By confirming that the thermal performance of Aboriginal housing is low, it is evident that housing quality is having a significant impact on energy stress.

Table 2: Summary of the *FirstRate5* results for Exisiting Aboriginal Housing in Walgett, as per the NatHERS Regime

House Number	Azimuth	Heating Load (MJ/m^2)	Cooling Load (MJ/m^2)	Total Load (MJ/m^2)	Star Rating
1	0	235	168.7	403.7	1.4
	90	222.7	171.6	394.3	1.4
	180	229.2	161.6	390.8	1.4
	270	235.7	176.7	412.4	1.4
2	0	231.8	165	396.8	1.4
	90	237.2	170.6	407.8	1.4
	180	251	162.3	413.3	1.4
	270	237.4	167.4	404.8	1.4
3	0	236.2	209.3	445.4	1.2
	90	219.9	200.1	419.9	1.3
	180	220.3	208.8	429.2	1.3
	270	236.4	211	447.4	1.2
4	0	219.3	202.9	422.2	1.3
	90	209.5	203.4	412.8	1.4
	180	217.6	198.3	415.9	1.4
	270	225.3	211.6	436.9	1.2
Average	-	229.0	186.8	415.9	1.3

Observing the values in Table 2, it is also interesting to note that according to the calculations that have been performed by FirstRate5, the existing houses have greater heating energy requirements than they do cooling energy requirements; suggesting that the houses are more comfortable in summer than they are in winter. This is surprising for a number of reasons, including:

1. It is well established that the region of NW NSW that Walgett belongs to is a cooling load dominated climate (BOM, 2019).
2. The fact that the AHO Air Conditioning Policy was implemented in response to complaints from tenants about housing in NW NSW being too hot, not too cold.

While the results calculated by FirstRate5 are unexpected, this could be due to the fact that the thermal calculations made by *FirstRate5* are not considering adaptive thermal comfort activities (such as rugging up with blankets to stay warm, lighting fire places to stay warm, taking showers to stay cool etc.) that Aboriginal householders in Walgett may be adopting to improve their thermal comfort. Further, it may be the case that the adaptive comfort activities adopted by householders in winter, are more effective at enhancing thermal comfort than the adaptive comfort activities adopted in summer. This could be the case, especially during periods of drought, if the majority of adaptive comfort activities for summer are water based, and there are strict water restrictions - preventing householders from being able to partake in these activities to enhance their thermal comfort.

While it is difficult to investigate the retrofit potential of the Aboriginal housing stock in Walgett without engaging a building contractor to advise what retrofit options are feasible in reality, *FirstRate5* has been utilised to parametrically examine how different building envelope retrofits could improve the thermal comfort of this housing in theory. Based on the architectural drawings that have been obtained for the existing housing stock, it was conservatively decided that the following building envelope retrofit options were to be explored in the following order:

- Add reflective foil to the roof space, and insulation to the ceiling (until diminishing returns reached)
- Add external awnings to glazing systems
- Add insulation to external walls (up to R1.5, to be conservative*)
- Add insulation below the flooring (until diminishing returns reached)

*It must be noted that without the advice of a building contract, it is challenging to know to what extent the external walls of the houses can be retrofitted with insulation. As a result, a conservative approach has been taken, and it has been assumed that no more than R1.5 insulation can be added to these walls.

A summary of the *FirstRate5* results for each retrofit option, when the houses are modelled for orientations of 0°, 90°, 180°, 270°, are presented in Tables 3-6.

Table 3: Summary of the *FirstRate5* results for Existing Aboriginal Housing in Walgett, when it is retrofitted with reflective foil to the roofspace and R4.0 insulation to the ceiling

House Number	Azimuth	Heating Load (MJ/m^2)	Cooling Load (MJ/m^2)	Total Load (MJ/m^2)	Star Rating
1	0	118.1	47.9	166	3.8
	90	108.4	52.6	160.9	3.9
	180	112.4	44.7	157.1	3.9
	270	119.4	57.6	177	3.6
2	0	111.4	50	161.4	3.9
	90	118.2	54.9	173.1	3.6
	180	134.2	47.2	181.5	3.4
	270	120.8	51.7	172.5	3.7
3	0	117.4	100	217.4	2.9
	90	102.9	94.2	197.1	3.2
	180	104.7	102	206.7	3.1
	270	119.2	100.3	219.5	2.9
4	0	103.6	80.6	184.3	3.4
	90	94.7	85.4	180.1	3.4
	180	101.8	81.5	183.3	3.4
	270	110.2	90.8	201	3.2
Average	-	112.3	71.3	183.7	3.5

Table 4: Summary of the *FirstRate5* results for Existing Aboriginal Housing in Walgett, when it is retrofitted with reflective foil to the roofspace, R4.0 insulation to the ceiling and external awnings to glazing

House Number	Azimuth	Heating Load (MJ/m^2)	Cooling Load (MJ/m^2)	Total Load (MJ/m^2)	Star Rating
1	0	118.2	47.2	165.4	3.8
	90	108.4	47.9	156.4	3.9
	180	112.5	44.6	157.1	3.9
	270	119.5	48.4	167.9	3.7
2	0	111.5	50	161.5	3.9
	90	118.4	48.4	166.8	3.8
	270	120.8	46.8	167.6	3.7
	180	134.2	47.1	181.3	3.4
3	0	117.6	89.1	206.7	3.1
	90	103	84.7	187.8	3.4
	180	104.9	87.9	192.8	3.3
	270	119.4	85.5	205	3.1
4	0	103.7	75.8	179.5	3.5
	90	94.8	77	171.8	3.7
	180	102	73.8	175.8	3.6
	270	110.4	79.6	190	3.4
Average	-	112.5	64.6	177.1	3.6

Table 5: Summary of the *FirstRate5* results for Existing Aboriginal Housing in Walgett, when it is retrofitted with reflective foil to the roofspace, R4.0 insulation to the ceiling, external awnings to glazing, and R1.5 insulation to external walls

House Number	Azimuth	Heating Load (MJ/m^2)	Cooling Load (MJ/m^2)	Total Load (MJ/m^2)	Star Rating
1	0	75.2	26.5	101.7	5.7
	90	67.5	29.8	97.4	5.9
	180	66.6	25.8	92.4	6.1
	270	73.6	31.6	105.3	5.5
2	0	70.5	29.6	100.1	5.7
	90	78.5	31.8	110.3	5.3
	180	90.2	29.3	119.5	4.9
	270	77.4	33	110.5	5.3
3	0	83.8	70	153.7	4
	90	72.3	68	140.3	4.4
	180	72.5	71.5	144	4.3
	270	83.7	69.9	153.6	4
4	0	63.1	53.9	117	5.1
	90	56.5	55.4	112	5.3
	180	61.3	54.7	116	5.1
	270	68.1	59.1	127.1	4.7
Average	-	72.6	46.2	118.8	5.1

Table 6: Summary of the *FirstRate5* results for Existing Aboriginal Housing in Walgett, when it is retrofitted with reflective foil to the roofspace, R4.0 insulation to the ceiling, external awnings to glazing, R1.5 insulation to external walls and R1.0 insulation beneath flooring

House Number	Azimuth	Heating Load (MJ/m^2)	Cooling Load (MJ/m^2)	Total Load (MJ/m^2)	Star Rating
1	0	68.9	31.1	100.1	5.7
	90	60.1	34.3	94.4	5.9
	180	58.4	30.8	89.2	6.2
	270	65.4	36.3	101.7	5.7
2	0	62.4	33.9	96.4	5.9
	90	69.8	35.6	105.5	5.5
	180	81.1	33.7	114.8	5.2
	270	68.9	37.3	106.1	5.4
3	0	77.5	75	152.5	4.1
	90	65.8	73.8	139.6	4.4
	180	64.8	76.9	141.8	4.3
	270	76.6	75.7	152.3	4.1
4	0	59.5	59.7	119.3	4.9
	90	52.1	61.4	113.5	5.2
	180	54.7	60.5	115.2	5.1
	270	62.3	64.7	127	4.8
Average	-	65.5	51.3	116.8	5.2

Recalling that the average HER for the existing houses was 1.3 stars, observation of Tables 3-6 reveals that by retrofitting the building envelope of existing houses, the average HER of the Aboriginal housing stock in Walgett could be increased by up to 3.9 stars. This knowledge is important as it suggests that, by retrofitting the building envelope of existing Aboriginal housing, the thermal comfort of this housing could be improved significantly. Further, by reducing the heating and cooling energy of the houses, it is evident how retrofitting the building envelope of existing housing could also substantially reduce the cost of providing auxiliary heating and cooling to homes, via heating and cooling equipment, such as air conditioning.

To compare the operational energy costs associated with providing adequate heating and cooling to the living rooms of existing Aboriginal housing, and Aboriginal housing that has been completely retrofitted, Figure 1 has been prepared. Figure 1 illustrates the average seasonal heating and cooling costs for the existing and completely retrofitted housing, when they are operating as per the *AHO Air Conditioning Policy* (i.e. when heating and cooling is only supplied to the living rooms of houses).

Observation of Figure 1 reveals that the operational energy costs (when considering heating and cooling) associated with retrofitted Aboriginal housing are drastically lower than the operational energy costs that are associated with existing Aboriginal housing. This suggests that, not only does retrofitting the building envelope of existing Aboriginal housing have the potential to improve the thermal comfort (by improving the thermal performance of houses), but also that it can be used to mitigate problems with energy stress and energy poverty caused by poor quality housing. It is important to note however, that these costs are only indicative. This is due to the fact that:

- The retail electricity tariff that Aboriginal householders in Walgett are subjected to has been assumed to be 24.39c/kWh, and that all householders may not be under this tariff arrangement
- The assumptions for building occupancy and operation used by *FirstRate5* in its assumptions maybe not be indicative of the way Aboriginal housing in Walgett is occupied and operated; therefore, unless qualitative analysis is conducted to confirm this, the values in Figure 1 could be over or underestimating the energy requirements of the houses.

- No Coefficient of Performance (COP) has been applied to the heating and cooling energy loads calculated by *FirstRate5* for this analysis, therefore the values in Figure 1 could be overestimating the energy needed to heat and cool houses.
- No information detailing the size of make of air conditioners installed under the *AHO Air Conditioning Policy* has been published, therefore it is difficult to determine the size of air conditioners installed under the policy. This analysis assumes the air conditioners were sized perfectly, though it this is unlikely to be the case; as a result, the values presented in Figure 1 could be over or underestimating the true cost of supplying adequate heating and cooling energy to homes, depending on whether the systems were over or under sized respectively.

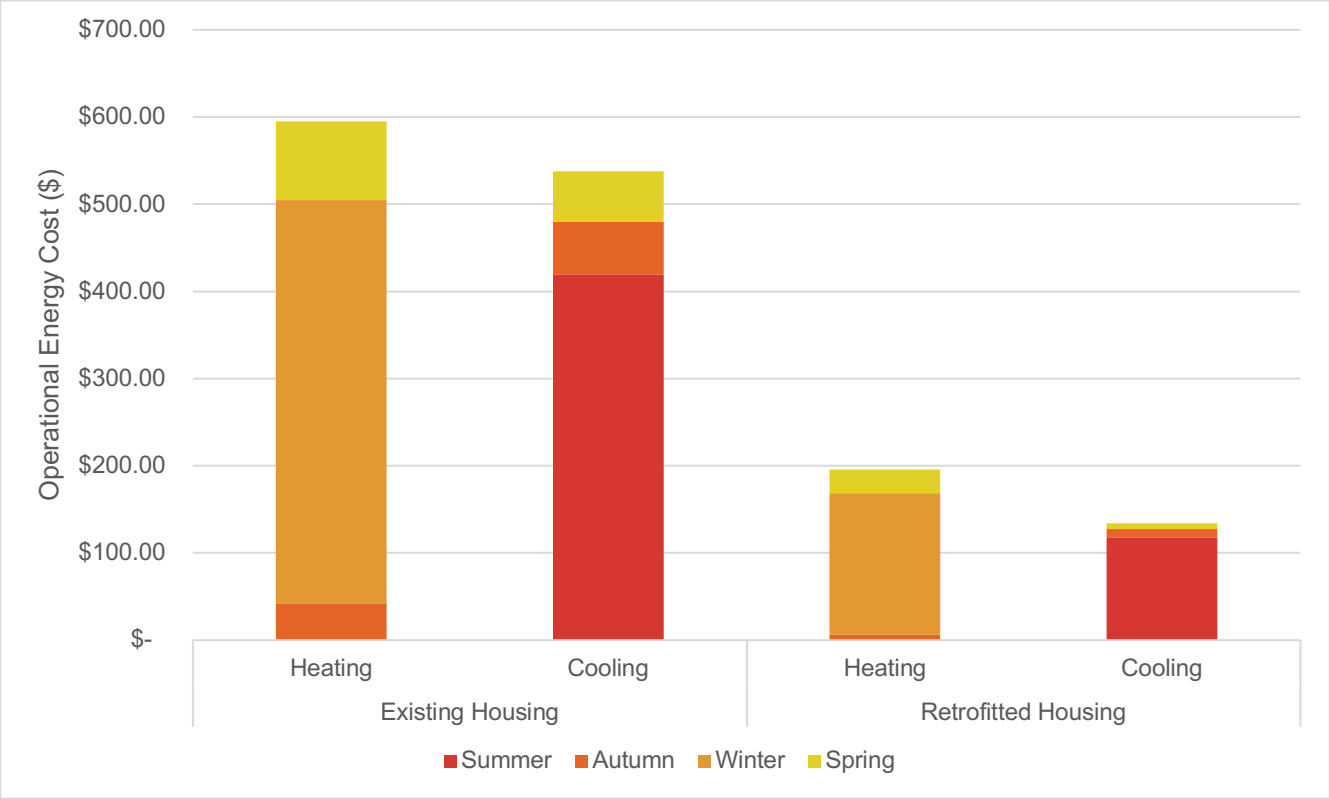

Figure 1: Breakdown of the Operational Heating and Cooling Costs for Exsiting and Retrofitted Aboriginal Housing in Walgett, Under the *AHO Air Conditioning Policy*

4. Conclusion

While it is evident that the thermal performance, and hence thermal comfort, of existing Aboriginal housing in Walgett, NSW is substandard, it has been shown that by retrofitting the building envelope of these houses, significant improvements to thermal performance of such housing can be realised. Although it is difficult to determine how realistically some retrofit options can be implemented in reality without the advice of a building contractor, it has been shown that by retrofitting the roof, ceiling, awnings, external walls and flooring of Aboriginal housing in Walgett, the average House Energy Rating of existing houses can be increased by up to 3.9 stars. Further, it has demonstrated that the act of retrofitting the building envelope of existing Aboriginal housing could be one way in which the risks and ramifications of energy poverty in Aboriginal communities, like Walgett, could be reduced. This is important knowledge for policy makers, and providers of Aboriginal housing, as it suggests how passive design could be used to alleviate problems pertaining to both thermal comfort and energy poverty.

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